Motivation

Sharper turn-on

- **Will use events with high efficiency only for physics analysis**
  - No need to waste bandwidth with events in turn-on

What can be done without any new effort?

- **Turn-on can be sharpened simply by combining 1, 2, 3 and 4 jet 4x4 thresholds.**
- **Accept a few kHz higher rate.**
- **However, community felt that they needed more accurate level-1 jet counting ability**

Implication of 12x12 algorithm

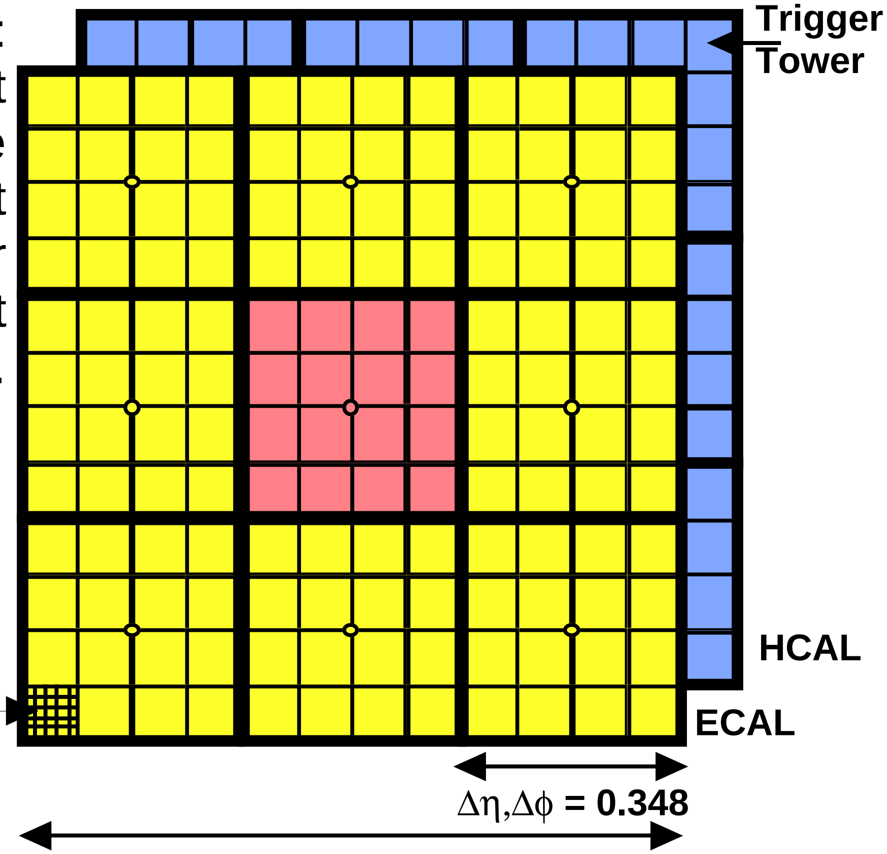
- **12x12 algorithm ~= 0.7 jet cone radius**
- **Sharper turn-on assured**
- **Better jet counting ability**
- **However,**
  - Loose physics in the turn-on portion
  - i.e., H(200 GeV) $\rightarrow \tau\ \tau \rightarrow$ h h X

Saviour

- **Dedicated τ algorithm**
- **Use bandwidth saved by sharpening the turn on for a narrow jet (τ) stream.**

Updated Jet, τ Algorithms

Input from E/HCAL: Programmable 8-bit non-linear scale converted into10-bit linear scale for sums to obtain jet or τ E_T.



Active towers counted after a trigger tower level programmable threshold. τ-veto bit formed by requiring that there be no more than 2 active ECAL or HCAL towers in a 4 x 4 region.

Jet or τ E_T

- **12x12 trigger tower E_T sums sliding in 4x4 steps with central 4x4 > others**

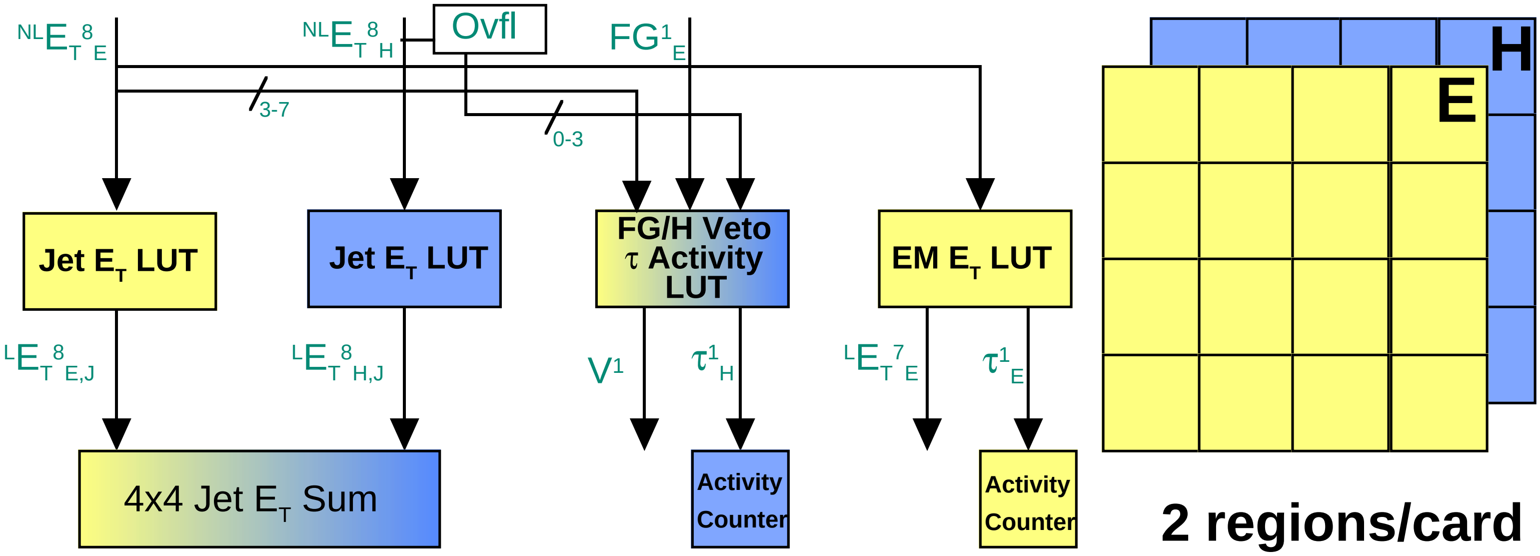
τ algorithm (isolated narrow energy deposits)

- **Redefine Jet as τ if none of the 9 4x4 region τ-veto bits are on**

Output

- **Sorted top 4 jets & top 4 τ-jets & counts of jets above programmable thresholds**

Jet/τ algorithm - receiver card



Minor revision of Receiver card LUTs

- **Jet E_T LUTs (1 for ECAL and 1 for HCAL)**
  - Nonlinear 8-bit to linear 8-bit for jet sums
- **EM E_T LUT**
  - Nonlinear 8-bit to linear 7-bit for EM algorithm
  - 1 ECAL activity bit for generating τ bit (new)
- **FG/H Veto/τ Activity LUT**
  - Address: bottom 4 bits HCAL non-linear E_T (pegged), top 5 bits ECAL non-linear E_T, FG bit
  - Data: 1 bit EM veto(no change), 1 HCAL activity bit (new)

4x4 Jet sum

- **Sum to obtain 10-bit 4x4 region sum**
- **Output to Jet/Summary card**

Activity Bit Counter (new)

- **Sum 16 bits per E and H region separately**
- **All logic runs at 4x**
- **Sums output to Jet/Summary card**

Jet/Summary Card

Input

- **From 7 receiver cards**
  - 2 4x4 region 10-bit E_T + overflow values
  - 2 4x4 region 2-bit activity counts (new)
- **From 7 EID cards**
  - 2 isolated electrons - 2 x 6-bit rank
  - 2 nonisolated electrons - 2 x 6 bit rank

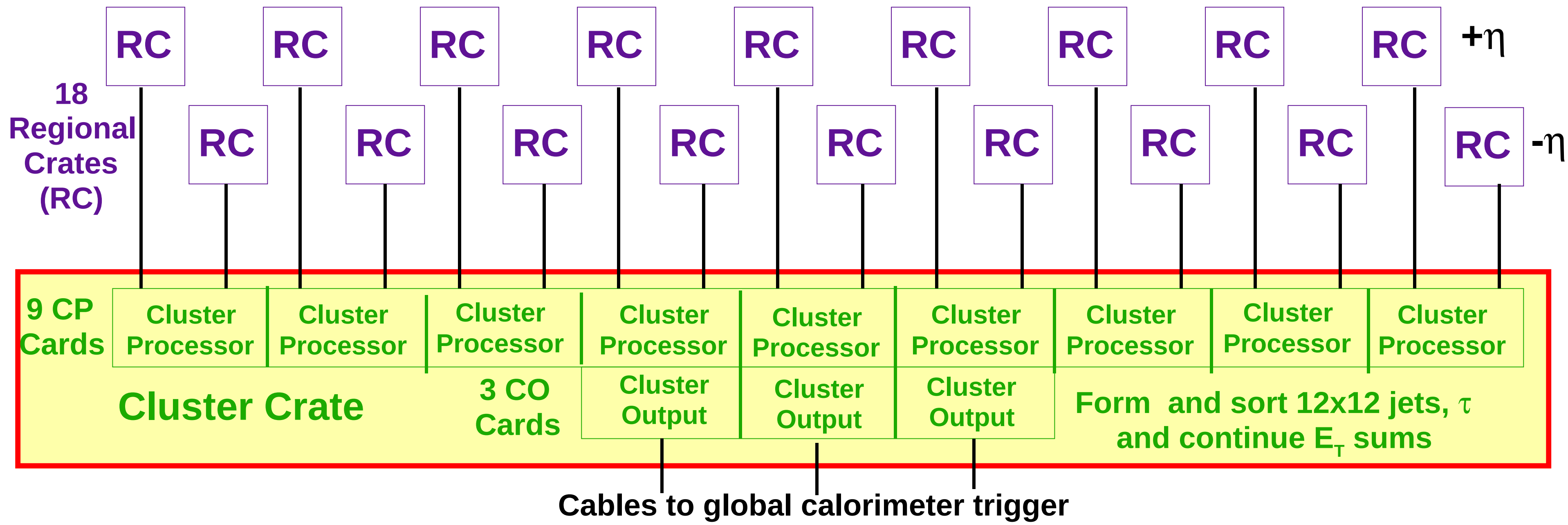
Processing

- **τ veto bit extraction for 14 4x4 regions (new)**
  - **τ veto bit set if E or H activity counts >2**
    - $\tau^1_V = (A^1_E \text{ AND } A^2_E) \text{ OR } (A^1_H \text{ AND } A^2_H)$
- **Threshold 4x4 E_T to get μ_{iso} bits**
- **Sort isolated & nonisolated electrons separately**

Output (For 18 HB/HE Crates)

- **To Cluster Crate (new)**
  - 14 regions x (10 bits E_T + ovfl + τ bit) = 168 bits
- **To Global Muon Crate**
  - 14 regions x (μ bit + μ_{iso} bit) = 28 bits
- **To Global Calorimeter Crate**
  - 8 x (6 bit E_T rank + 4 bit position) = 80 bits
    - Top 4 isolated electrons
    - Top 4 non-isolated electrons

Implementation: Cluster Crate



Regional Crates send 4x4 energies and τ-veto bit to cluster crate

- Uses diff. ECL links at 80 MHz - same as proven existing inter-crate sharing

Cluster crate shares data on a custom 160 MHz ECL point-to-point backplane

- Similar to existing regional crate backplane - same proven technology

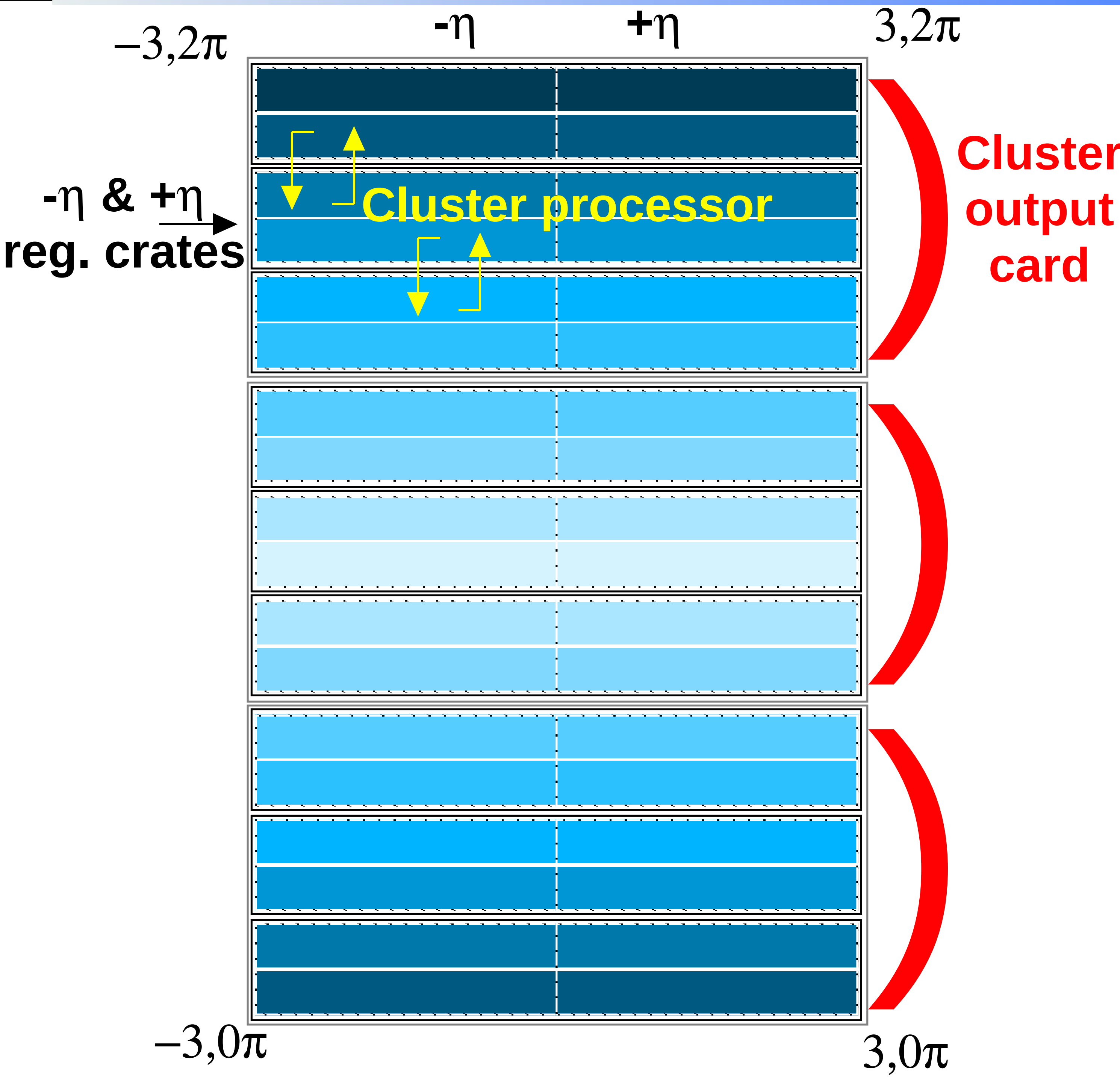
Cluster crate uses 160 MHz Adder and Sort ASICs (Minimum additional latency)

- Existing Adder ASIC - already in production, just order more

Global calorimeter data

- Receives data for half the number of candidates but two types: jet and τ

Cluster crate



9 Cluster processor cards

- **Each covering 40° ϕ x 6 η**
- **Input from 2 (+η and -η) regional crates**

3 Cluster output cards

Jet/τ algorithm - clustering

Cluster Crate

- **Clusters E_T to 12x12 tower regions**
- **Classifies as jet or τ, ranks, sorts**
- **Forwards top 4 jets &τs to global calorimeter trigger**

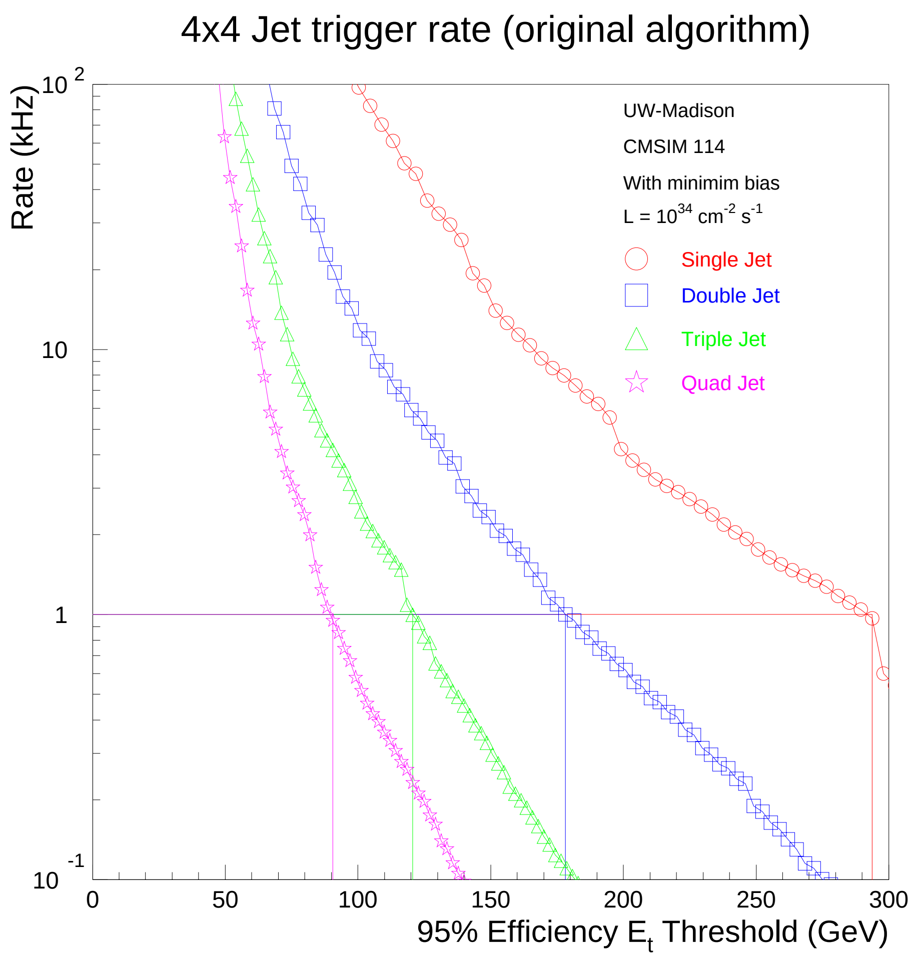
Cluster Processor Cards (9)

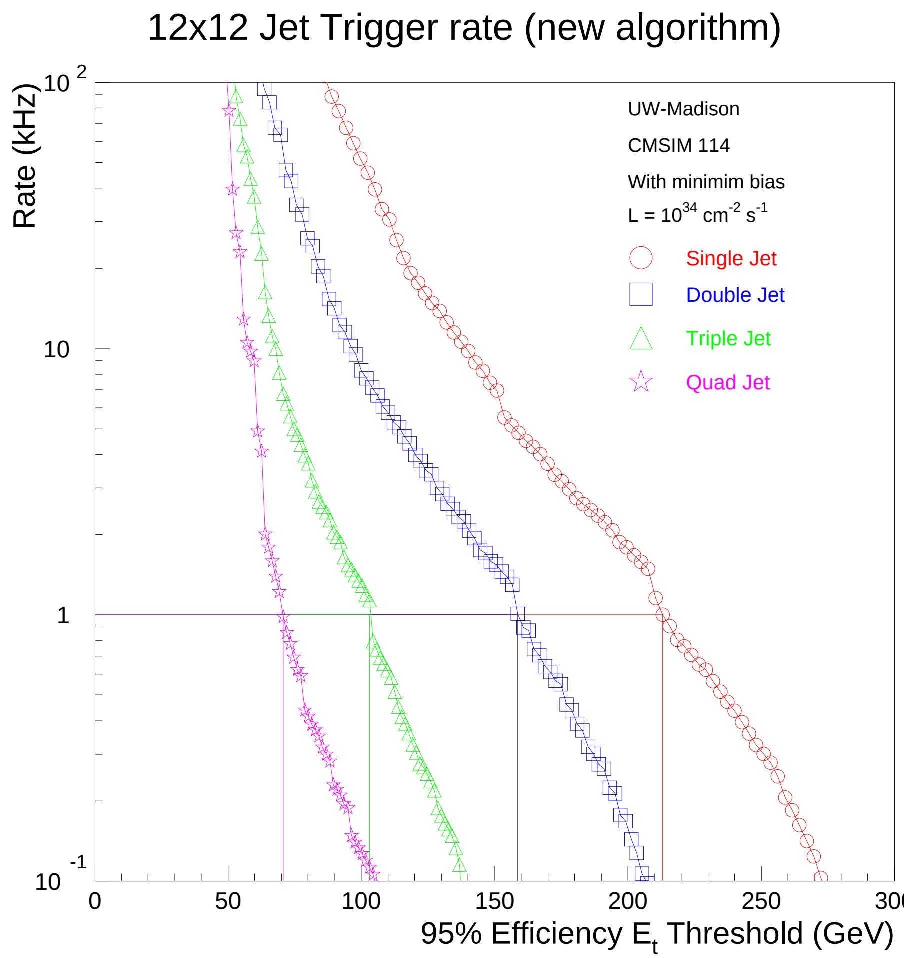
- **Receive data from +η and -η regional crates**
  - Two 20° φ regions per regional crate
  - 2 x 14 η towers x 12 bits = 336 bits
- **Share neighbor data for two 20° phi regions**
  - Backplane data sharing for overlap = 336 bits
- **Sum 3x3 region, i.e., 12x12 tower, energies with the center greater than neighbors (prevent double count) requirement**
  - Convert result to 6 bit rank and 5 bit position
  - Result: 28 candidates
    - Classify as τ if all 3x3 τ veto bits = 0 - otherwise as jet
    - Sort to find top 4 jet candidates
    - Sort to find top 4 τ candidates
- **Sum +η and -η 20° φ sectors to get four E_T values**
  - 10 bit energy + 2 bit overflow (OR the overflows)
- **Transfer output to Jet Cluster Output Card**
  - 4x11 bits (jets) + 4x11 bits (τs) + 4x11 bits (E_T) = 132 bits

Cluster Output Cards (3)

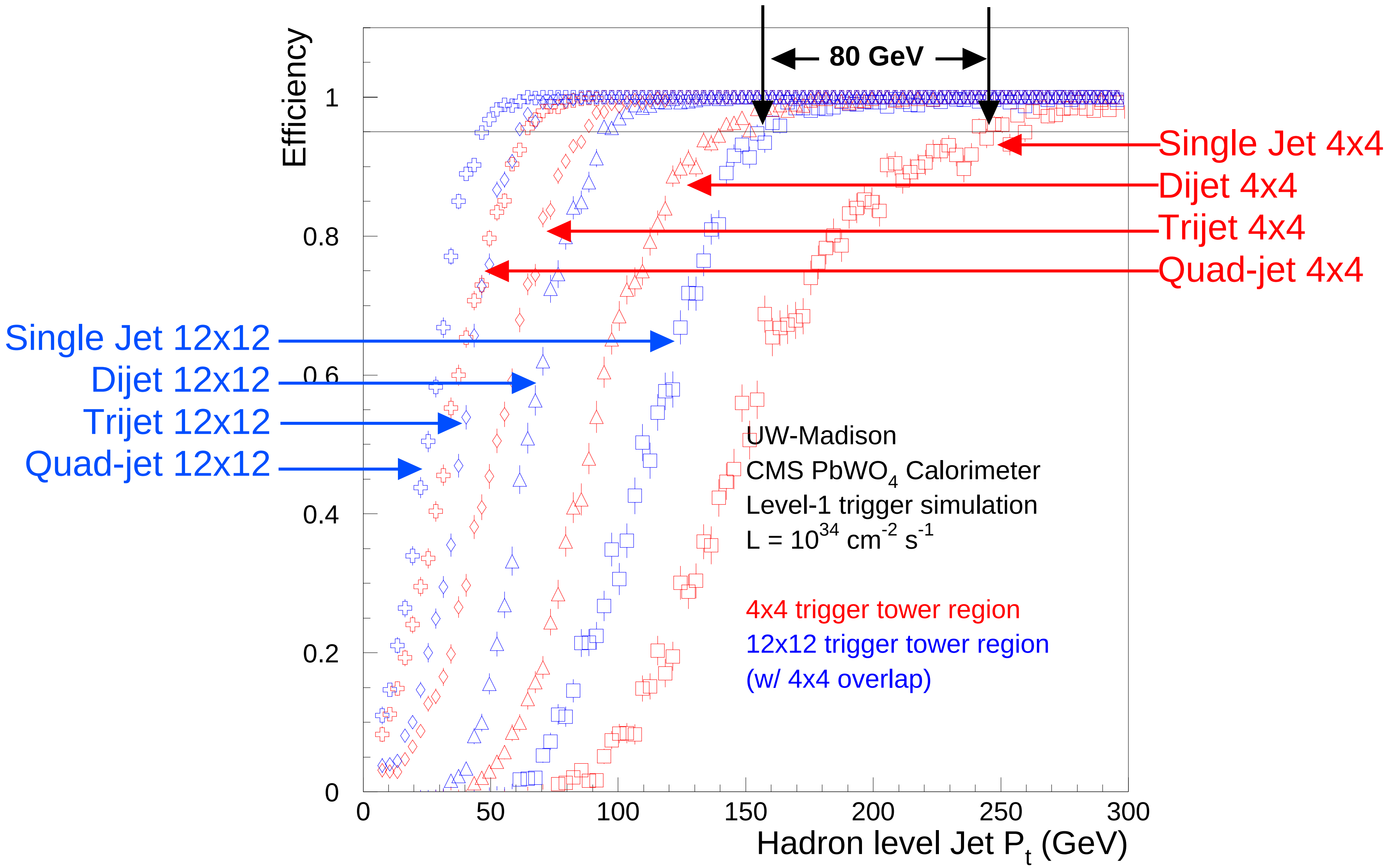
- **Receive data on backplane from 3 Jet Cluster Processor Cards (3x132 = 396 bits)**
- **Output all data to Global Calorimeter Trigger**
  - 396 bits on 6 cables

Jet rate comparison

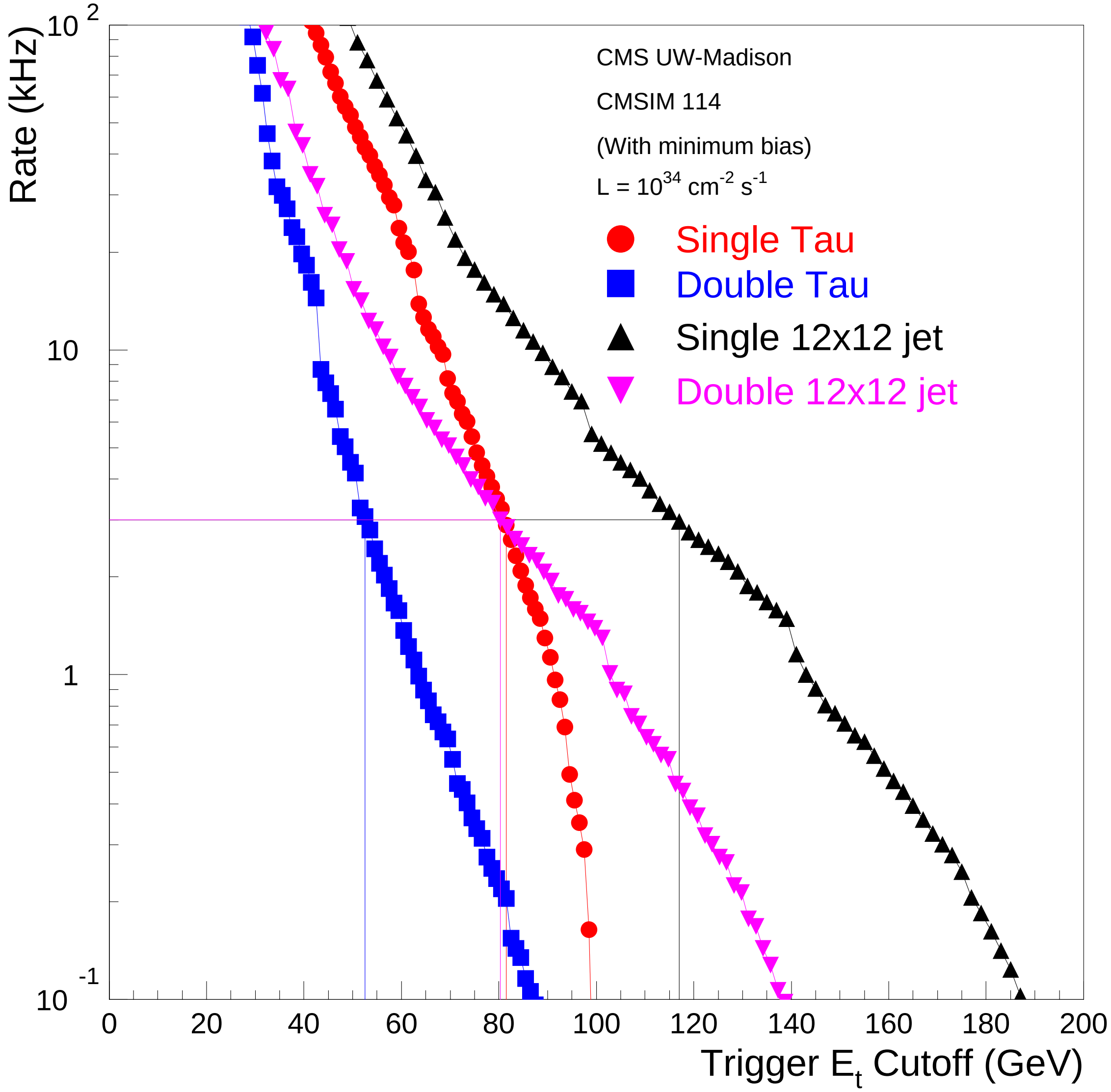




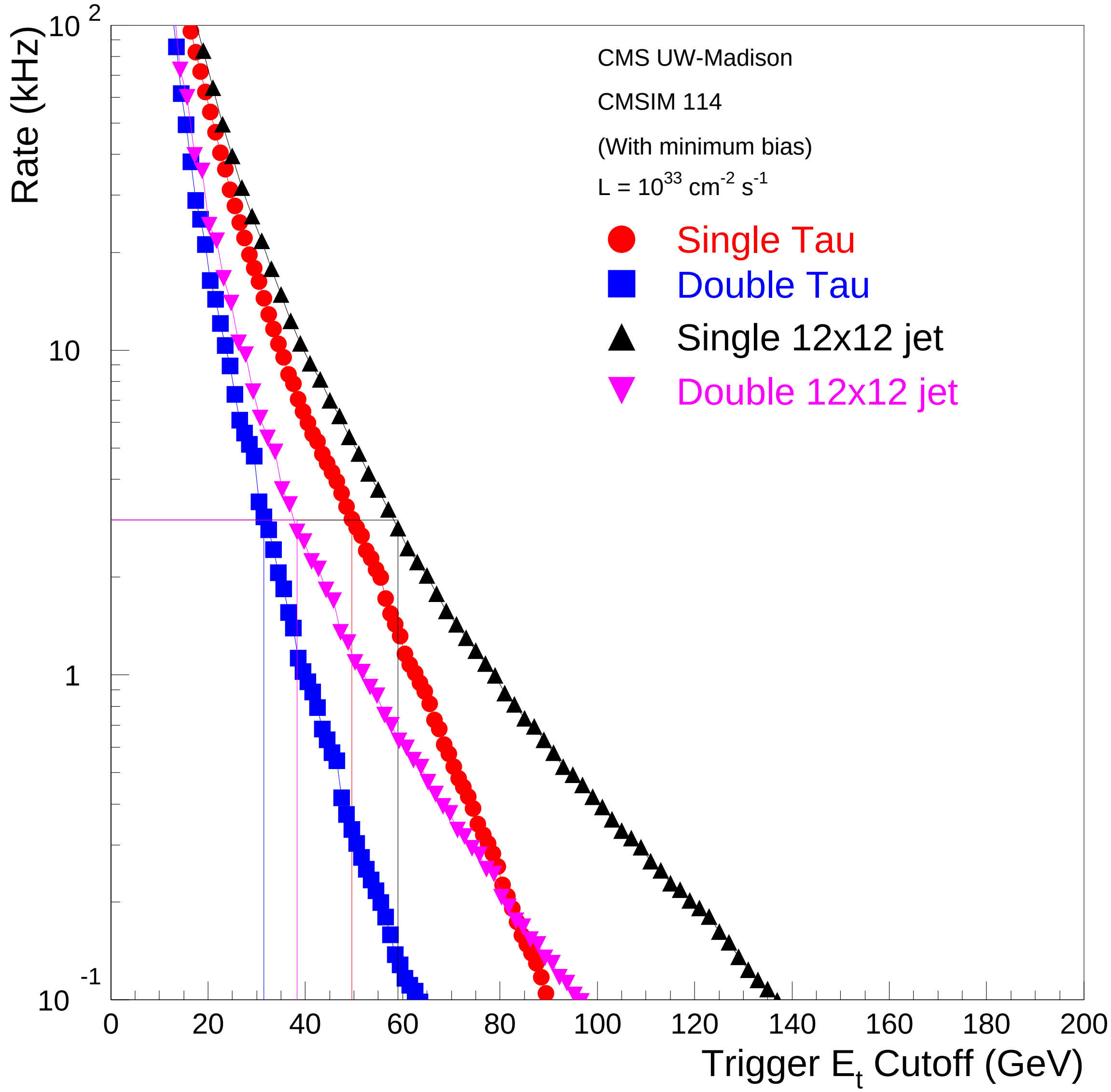
Jet efficiency comparison



High Luminosity τ trigger rate



Low Luminosity τ trigger rate



SUSY Higgs (M_H=200 GeV, tanβ=15)

H(200 GeV) $\rightarrow \tau\tau \rightarrow$ 2 hadrons + X
Efficiency Comparison
Baseline algorithms vs new τ algorithm

	High Luminosity	Low Luminosity
All baseline algorithms	22.2%	86.4%
Just the new τ algorithm	37.2%	76.1%

Algorithm cutoffs are to be further optimized:

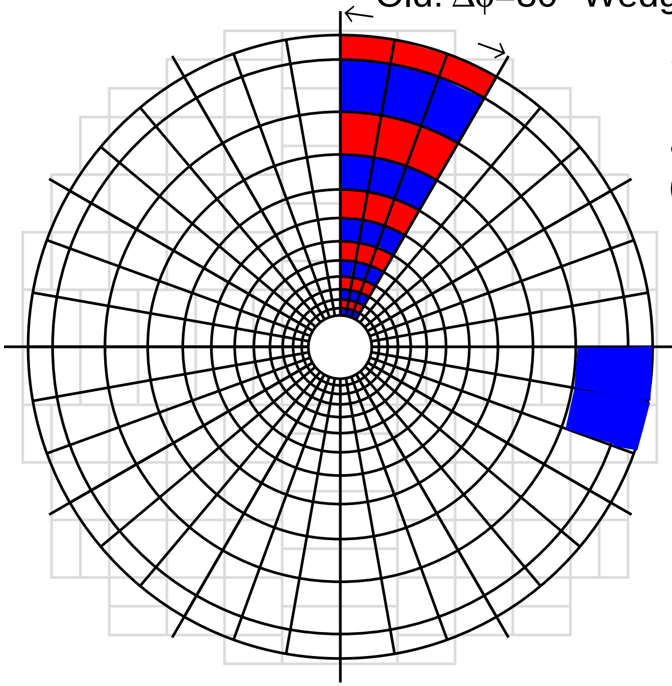
- High lumi: single τ E_T > 80 GeV, double τ E_T > 40 GeV
- Low lumi: single τ E_T > 50 GeV, double τ E_T > 30 GeV

HF Trigger Mapping

New: 2 CMS HF Calorimeters mapping onto 12 32-Channel Receiver Cards

Old: 2 CMS HF Calorimeters mapping onto 6 **32**-Channel Receiver Cards

Old: $\Delta\phi$=30° Wedge$\Rightarrow$half Receiver Card - 12 Channels



Each Receiver Card handles two 30° Wedges, one forward and one backward at same ϕ (using **24** out of **32** available channels)

New: $\Delta\phi$=20° Wedge$\Rightarrow$ quarter Receiver Card - 6 Channels

Each Receiver Card handles two 20° Wedges, one forward and one backward at same ϕ (using 12 out of **32** available channels)

Readout segmentation: 36$\phi \times$ *12*$\eta \times$ *2z* $\times$ *2F/B*

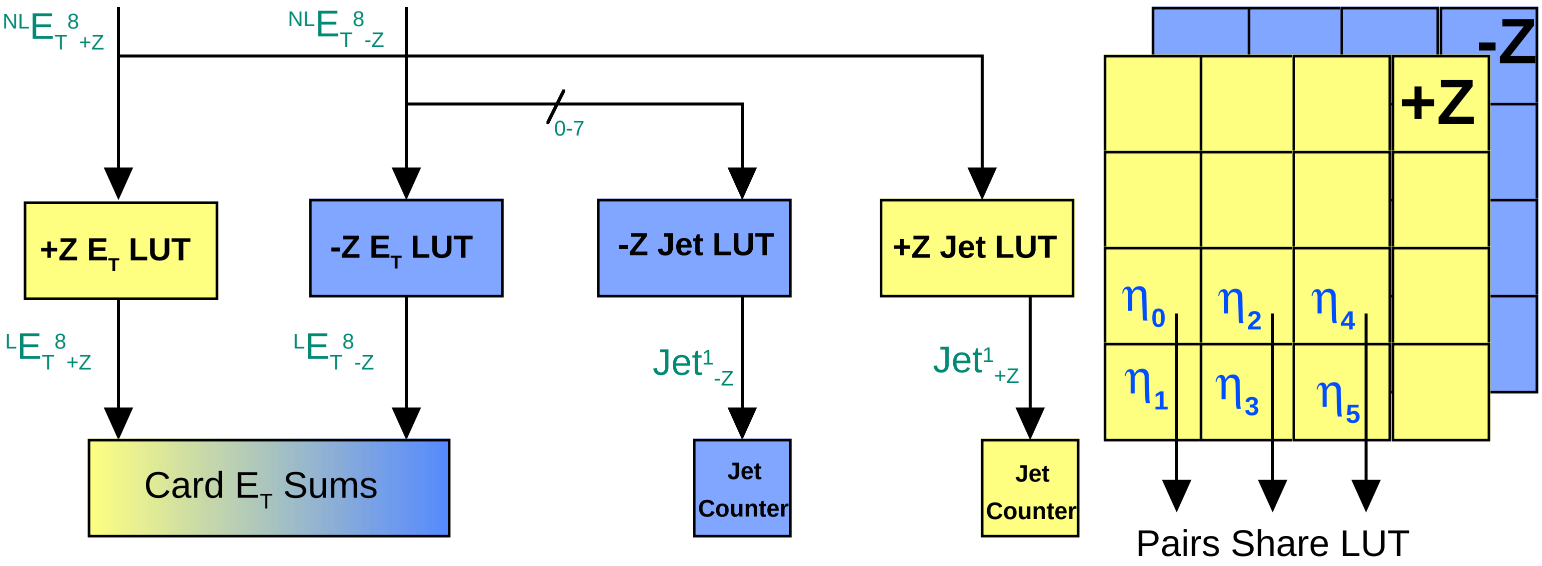
New Trigger Tower segmentation: 18$\phi \times 6\eta \times$ *2F/B*

Old Trigger Tower segmentation: 12$\phi \times$ *12*$\eta \times$ *2F/B*

Updated so that HB, HE and HF all use 20^0 ϕ divisions

- **No simulation studies with HF yet**
    - ORCA implementation of trigger primitives & algorithms in progress

HF algorithm - receiver card



Receiver card memory lookup tables - Reprogrammed for HF

- **+Z and -Z E_T LUTs**
  - Nonlinear 8-bit to linear 8-bit for E_T sums
- **+Z and -Z Jet LUTs**
  - Nonlinear 8-bit to 1-bit jet threshold bit
- **Address bits for -Z Jet LUT are $^{NL}E_{T\ +Z}^{\ 8}$ instead of $^{NL}E_{T\ H}^{\ 0\text{-}3}$, $^{NL}E_{T\ E}^{\ 3\text{-}7}$ and FG.**

E_T sum for each of 2 ϕ regions

- **Sum +Z and -Z towers together to obtain E_T sum - same as HB/HE**
- **Up to 16 η towers can be accommodated (using 6 now)**

Jet count for each of 2 ϕ regions

- **Same counter as HB/HE activity counter**
- **Sum up to 16 bits per +Z or -Z region seperately to obtain 2 2-bit sums pegged to 3 on overflow**

Output to HF Summary Card for each of 2 ϕ regions

- **10 bit E_T sum + 1 bit overflow**
- **+Z and -Z jet counts**

HF algorithm - summary

Two HF Crates

- **Each with 9 20º ϕ regions**
- **5 receiver cards (mods. on previous slide)**
  - One card is half used
- **HF summary card (different from J/S card)**
- **2 receiver card and 7 EID card slots unused**

HF Summary card (Variant of Jet/Summary card)

- **HF Jet Counting**
  - Continue +Z and -Z HF-jet count sums (separately) to get crate level 3-bit +Z and - Z HF-jet counts
- **HF E_T sums**
  - Just pass through

HF Output

- **To Global Calorimeter Crate**
  - 105 bits per crate
    - 3 bits +Z jet count
    - 3 bits -Z jet count
    - 9 ϕ regions x (10 bit E_T sum + 1 bit overflow)

Global Calorimeter Trigger

Output to Global Calorimeter Trigger

- **From 18 regional crates**
  - NonIso elec: 18 x 4 cand. x 10 bits (4 bit loc)
  - Iso. electrons: 18 x 4 cand. x 10 bits (4 bit loc)
- **From 1 cluster crate**
  - Jets: 9 x 4 candidates x 11 bits (5 bit loc)
  - Taus: 9 x 4 candidates x 11 bits (5 bit loc)
  - HB/HE E_T: 18 ϕ regions x 2 (+Z & -Z) x 11 bits
- **From 2 HF crates**
  - HF E_T: 2 x 9 ϕ regions x 11 bits
  - HF Jet counts: 2 x 2 (+Z & -Z) x 3 bits

Global Calorimeter Functions

- **Sort non-iso & iso electrons, jets and taus**
  - 6 bit E_T and 8 bit location for top 4 objects of each of the four types
- **Convert E_T sums to E_X and E_Y and sum**
  - Calculate missing and total E_T information
- **Jet count**
  - HB/HE counts (in η ranges), +Z and -Z HF
- **Make Luminosity histogram**
  - 18 ϕ x 2 η bins

Summary

New τ and jet algorithms

- Conceptual design done
  - Small modifications to regional trigger Receiver card, Backplane and Jet/Summary card
- New cluster crate
  - Cards, components and functionality identified
  - Design based on proven technology
    - Data sharing at 160 MHz with a different version of existing backplane
    - Existing 160 MHz Adder and Sort ASICs
- Design features
  - Minimum additional latency
  - Minimal risk - proof of principle exists
- Performance
  - Initial results look good
  - Can be optimized further
  - Simulation code being implemented in ORCA